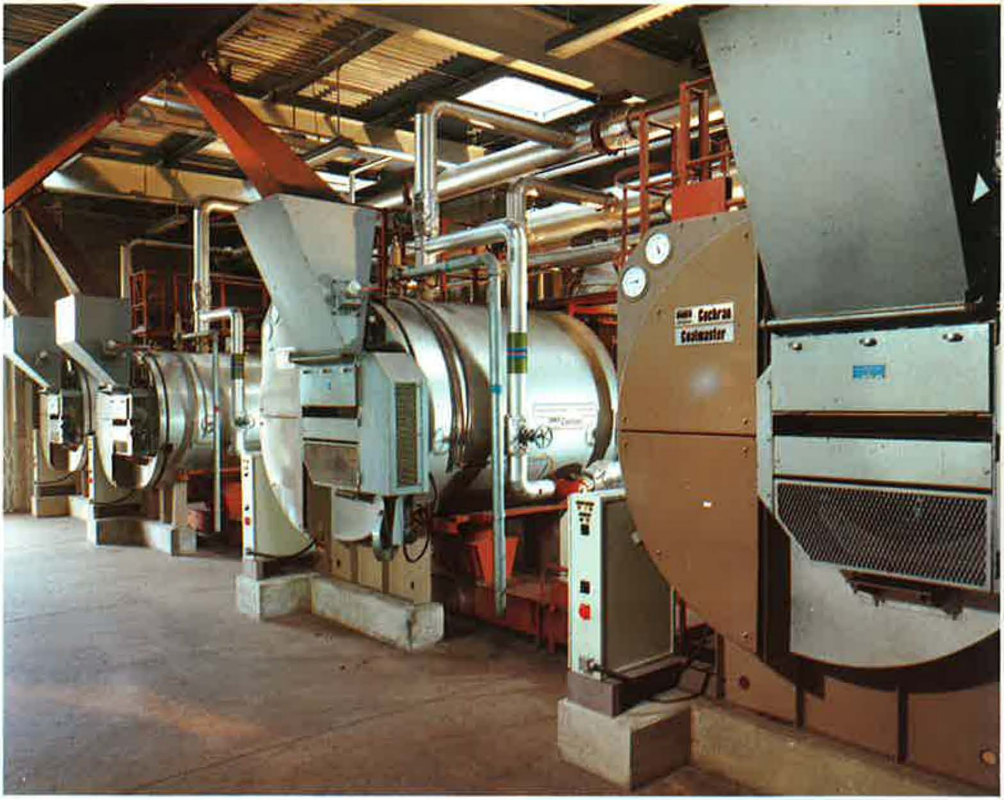
Economic Use of Coal-Fired Boiler Plant



BEST PRACTICE PROGRAMME

Energy Efficiency Office

DEPARTMENT OF THE ENVIRONMENT

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Economic use of coal-fired boiler plant

The views expressed in this Fuel Efficiency Booklet are not necessarily those of the Department of the Environment, Energy Efficiency Office, ETSU or BRECSU.

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1. Introduction

Steam and pressurised hot water boiler plants in industry and commerce vary in capacity from 100 kW to 30 MW (341,000 BTU/h to over 102 million BTU/h). This booklet relates mainly to shell boilers, which cover the middle range of capacity, of which there are many thousands in operation for heating and process applications. Much of the information is also relevant to other types of boilers.

This booklet provides guidance on the ways in which fuel and therefore money can be saved in the operation of boiler plants. The approach used examines the plant from fuel delivery, progressively through to the final heat output and identifies and quantifies the losses. Finally, there is a check list of money-saving procedures.

In order to show savings in perspective, reference is made to an example plant having a coal bill of £300,000 per year. Individual cases obviously need their own examination but nevertheless it is hoped that the inclusion of a quantitative example will help to give an indication of the possible savings that users can make.

Many boiler plants are operating at lower efficiencies than can be achieved and, moreover, maintained. The potential savings in fuel can be worthwhile. This booklet will tell you how to obtain them.

2. Background information

2.1 Fuel purchasing

Economies can often be achieved in the contract negotiated with the supplier, where the price paid may be expected to fall with increasing length of contract. Similarly, price concessions could be expected for taking larger consignments, if present deliveries are not being made in the largest size of lorry, and for stocking coal during the summer.

In any given plant it is probably unlikely that a different grade of coal can easily be adopted, because the initial specification of the boiler combustion equipment, delivery arrangements and coal handling plant would all be based upon the fuel originally selected. In the unlikely event that the boiler is hand-fired with coke, consideration should be given to conversion to automatic firing with coal. Some thought could be given to buying coals of slightly lower quality, perhaps with lower calorific value or higher ash content, but such decisions hinge essentially on associated technical considerations and the Technical Service staff of British Coal or the fuel supplier should be consulted.

2.2 Stocking

If it is decided to take larger consignments of coal or to stockpile it in greater quantities more storage space may be required, although if the whole of the stock is held in indoor bunkers, extension may be difficult. Outdoor stockpiles are more flexible in this respect but all such stockpiles or extensions to them should be laid on hard or compacted surfaces to avoid loss of fuel into the ground. The use of brick or concrete walls to form the bays contributes to efficient tipping and reclamation. Fresh coal loses a little of its heating value when in stock, but this deterioration is only slight and no further loss occurs after several months. For this reason, when large stocks are held, it is better to use the most recently delivered coal and leave the older stock untouched as far as possible. Vertical silos are being used increasingly, since they offer reduced storage space and facilitate automatic coal handling.

2.3 Coal and ash handling

In a properly designed and operated plant, expensive manual labour should be minimal. Careful watch should be kept for obvious gaps in the smooth progress of either coal or ash. For example, hoppers on combustion equipment may be filled by hand when, for a reasonable outlay, a screw elevator could be employed, freeing the attendant for other duties. Large plants may benefit from changes in handling equipment; some of the more recently introduced devices such as the pneumatic handling system (Fig 1) can be expected to offer savings in both operational and maintenance costs. Quite often, coal conveyors may be found running unnecessarily, resulting in a serious waste of expensive electrical energy.

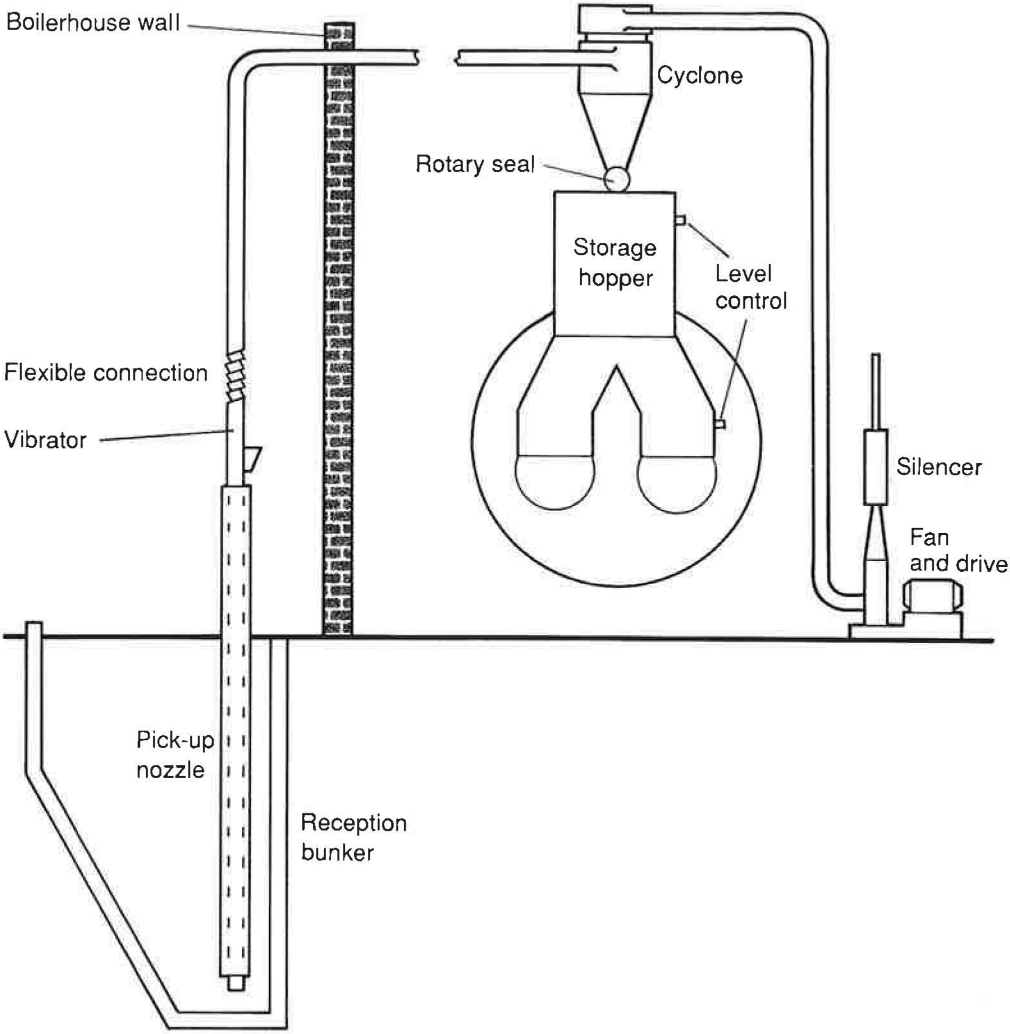


Fig 1 Pneumatic coal-handling system

2.4 Pollution control

Energy savings cannot be looked at in isolation and must not be achieved at the cost of increased waste emissions.

Depending on their size, boilers are dealt with by either the Clean Air Act Regulations or the Environmental Protection Act. Boilers under 20 MW come under the Clean Air Act, whilst boilers in the size range 20 - 50 MW are covered by Part B of the Environmental Protection Act (EPA). HMIP (Her Majesty's Inspectorate of Pollution) is now responsible for larger boilers where aggregated fuel inputs exceed 50 MW on a net calorific value basis. With the implementation of the EPA, a requirement for BATNEEC (best available techniques not entailing excessive expenditure) is now enforced, replacing the previous 'best available means'. In setting emission limits, HMIP takes into account the costs of installing further pollution abatement equipment. If this is viewed to be excessive, then further control may not be required.

In addition to the expected emissions of sulphur and nitrogen compounds and carbon dioxide, it is recognised that ash and grit from coal-fired boilers contain undesirable substances such as heavy metals. These are also potential environment pollutants and, as for other emissions, their disposal and dumping will be subject to greater control in the future.

3. Factors affecting the efficient use of energy

3.1 Example boiler

An Example Boiler is used to illustrate the significance of savings (Fig 2). The details are as follows:

Boiler efficiency based on gross calorific value:	
Flue gas losses	17%
Radiation losses, etc.	2%
Blowdown loss	3%
Ash losses, etc.	3%
Boiler efficiency	100 – 25 = 75%
Flue gas temperature	215.5°C (420°F)
Feed water temperature	17°C (62.5°F) (assumes mains water at 10°C (50°F) and 25% condensate return at 38°C (100°F))
Steam production	1.25kg/s (10,000 lb/hr) 24 hours per day, all year
Steam pressure	7 barg (100 psig)
Steam temperature	170°C (338°F) (dry saturated)
Cost of bituminous coal at approximately £60/tonne	£300,000 per year
Tonnes of coal per year	5,000

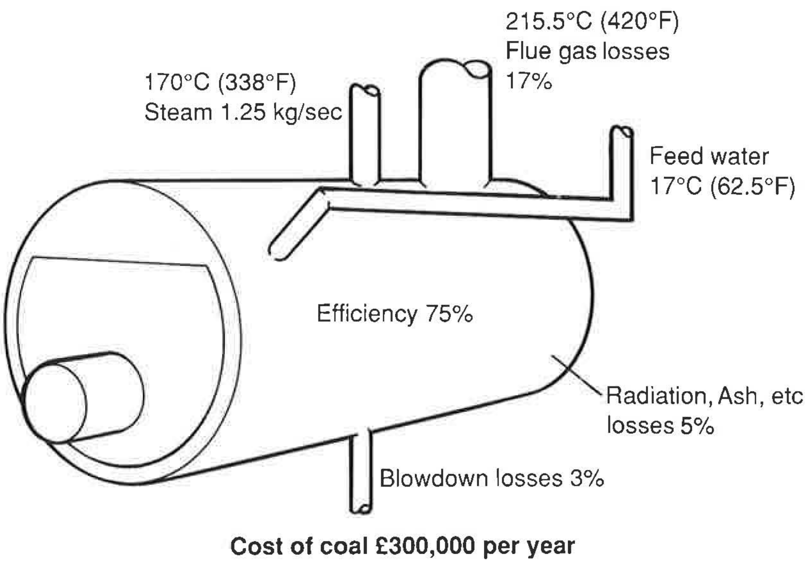


Fig 2 Example Boiler

For a boiler to maintain continuous output 24 hours per day, every day of the year, may be unrealistic from the operational point of view, but the condition provides a simple basis for making comparisons. Similarly, the boiler efficiency of 75% has been chosen so that improvements can be suggested. Many boilers do not even attain this level of performance, but a well operated shell boiler of modern design can be expected to have a thermal efficiency in excess of 78% at its designed output.

3.2 Mechanical stokers

A possible cause of inefficiency with mechanical stokers arises when boilers are de-rated, or for any other reason are run for long periods below design rating. In such cases it may happen that the firing equipment is, in effect, oversized for the duty performed, resulting in inefficient combustion. This can be corrected by installing shorter chain grates, or shorter bars in the case of coking stokers.

A loss directly attributable to fuel can occur when chain grate or coking stokers are fired with smalls that are too dry. In such cases the small particles can fall through the grates and be wasted. Wetting the coal, to the point that it will 'ball' when squeezed in the hand, will prevent this loss. Conditioning with water can also help to prevent particle segregation which can be the cause of poor burn-off on chain grate stokers.

3.3 Boiler thermal efficiency

Minimum costs are achieved by running boilers at high thermal efficiency. This section examines the various losses and draws attention to how they can be minimised.

The heat losses from boilers include losses from the flue gases, referred to as the flue gas losses; losses from the outside of the boiler, referred to as radiation losses; other incidental losses; and losses through blowdown. This can be expressed in basic equation form:

> boiler thermal efficiency % =
> 100% − (flue gas losses % + radiation losses %
> + incidental losses % + blowdown losses %)

Detailed procedures and calculations for assessing these and other losses can be found in BS 845: 1987 'Methods for assessing thermal performance of boilers for steam, hot water and high temperature heat transfer fluids'; however, as only simple monitoring of boiler performance is under consideration, the principal losses referred to above are all that need be investigated.

Calculations in this booklet are based on the gross calorific value of the fuel. Where the heat content of fuels or boiler efficiencies are quoted, it is important to be clear whether they are on a gross or net basis. It is essential to understand these terms. All fuels contain some hydrogen which when burned produces water in the form of steam. The latent heat in this steam is not recovered unless condensation occurs. The gross calorific value includes all the available heat, whereas the net value is the gross less the latent heat of vaporisation.

When gross values are used in the above equation, the flue loss item includes the heat in the steam, and when net values are used this heat loss is excluded. For this reason a boiler efficiency quoted on a net basis is numerically higher than that on a gross value, although the actual heat output is identical. Net values are frequently used in most European countries. For calculations like those in this booklet, the gross value is used as it is the simplest to correlate to fuel costs which are related to a gross calorific value. The difference between gross and net values is approximately 5%.

3.4 Flue gas losses

This comprises a number of separate losses but only the principal losses are considered here. These consist of the heat in the dry flue gases together with the heat in the moisture in the flue gas; the moisture is that introduced with the fuel, together with the further quantity resulting from the combustion of hydrogen in the fuel.

- ***Fuel-to-air ratio***

To achieve a high thermal efficiency, thereby minimising fuel costs, the amount of combustion air required should at all times be limited to that necessary to ensure complete combustion of the coal. In practice this means supplying air in

Savings or losses due to changes in efficiency

Simple calculations reveal possible savings or losses due to changes in efficiency. Given the efficiency values, the effect on the fuel cost is as follows:

$$\text{Change in fuel cost} = \text{original cost in fuel} \times \frac{\text{new efficiency} - \text{original efficiency}}{\text{new efficiency}}$$

Taking the Example Boiler with an efficiency of 75%, if the efficiency is raised by 4% to 79% the saving would be:

$$\text{Fuel saving} = 300{,}000 \times \frac{79 - 75}{79} = £15{,}190$$

excess of that which is theoretically necessary, but keeping the excess air to a minimum. The amount of excess air giving the optimum boiler efficiency will depend on the fuel used, the type of boiler, its state of repair and method of operation, the skill of the operator (for boilers with manual control) and the combustion equipment.

Heat is transported to the flue by the excess air. Consequently, as the amount of excess air increases, the loss of heat to the flue and the running cost also increases. On the other hand, if the air rate is too low, a proportion of the fuel will remain unburned, smoke will be generated and again the running cost will be increased. The type of controls fitted to the stoker and their adjustment will determine the results that can be achieved. The boiler and stoker supplier should be consulted to find out the best settings.

Experience has shown that in practice stoker controls may be incorrectly adjusted, with excess air often too high, leading to correspondingly high flue gas loss. In these cases, the controls should be adjusted in accordance with the boiler/stoker maker's instructions. Provided that the stokers are well maintained, adjusted to suit the fuel being used, and operated in accordance with the maker's instructions, the fuel-to-air ratio controls on modern boilers should be able to maintain the recommended excess air throughout the full turndown range. On larger boiler plants, operating under high load conditions, it will often prove economic to fit automatic fuel-to-air ratio controllers which will maintain boiler efficiency.

To check that the fuel-to-air ratio is correct, the usual method is to analyse the flue gases leaving the boiler. By finding out the composition and temperature of these gases, the losses to the flue can be assessed. A chart showing the relationship for bituminous coal is given in Fig 3. The losses indicated on the right of the graph are those due to heat in the dry gas and moisture.

- ***Flue gas analysis***

Mechanical stokers can be found operating at anything from 30 - 80% excess air or even more, giving 14 - 10% carbon dioxide (CO_2) or less in the flue gas (see Fig 3). Clearly, it is desirable to attain the higher levels of CO_2 in order to minimise heat loss. It is therefore important to monitor the CO_2 or oxygen (O_2) concentration in the flue gas, to check that the level of excess air is being properly controlled.

The performance and efficiency of boilers should be regularly checked with a flue gas CO_2 or O_2 analyser and flue gas thermometer. These give a direct read-out of efficiency removing the need for calculations, and can be obtained in portable kits costing about £1,000 to £2,000. Portable kits which test for sulphur and nitrous oxides (SO_x and NO_x respectively) can be obtained for a cost of around £5,000. The greater expense of a permanent installation or the use of more expensive equipment such as the SO_x and NO_x analyser, may be justified for larger plant or where there are several boilers. Testing for carbon monoxide (CO) is a further refinement as a check on combustion efficiency.

When using a portable kit, the flue gas samples should not be diluted by air inleakage which would alter the flue gas analysis. In addition the sample points should be thoroughly purged

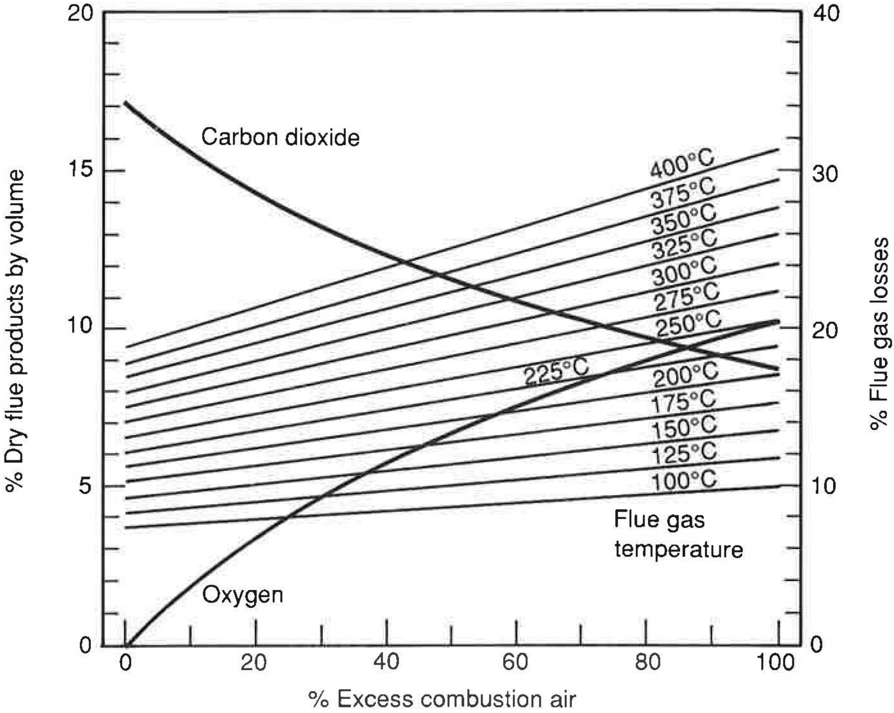


Fig 3 Flue gas losses – bitumous coal

before aspirating the sample, to ensure that the sample tube is free of obstruction.

Many boilers have no sample point, but on packaged units this can easily be provided by drilling a small hole in the metal outlet, as close to the boiler as practicable. Care should be taken to ensure that the sample is representative of the flue gas, by traversing across the flue and assessing and correcting for any variations in CO_2 or O_2.

Savings or losses due to flue gas composition change

If, in the Example Boiler, circumstances allowed the percentage of CO_2 in the flue gas at 215.5°C (420°F) to be increased from 9.8 to 11.8%, the flue gas losses would be reduced from 17 to 15% (see Fig 5). The boiler efficiency would be improved by 2% to 77% resulting in a saving in the fuel bill of:

$$£300{,}000 \times \frac{(77-75)}{77} = £7{,}792 \text{ per year}$$

This example is illustrated in Fig 4, for bituminous coal, to show how the graph is used.

If, however, the percentage of CO_2 in the flue gas were to fall from 9.8 to 8.5%, the flue gas losses would rise and the boiler efficiency would fall by 2% to 73%. This would result in an increase in the annual fuel bill of:

$$£300{,}000 \times \frac{(73-75)}{73} = £8{,}219 \text{ per year}$$

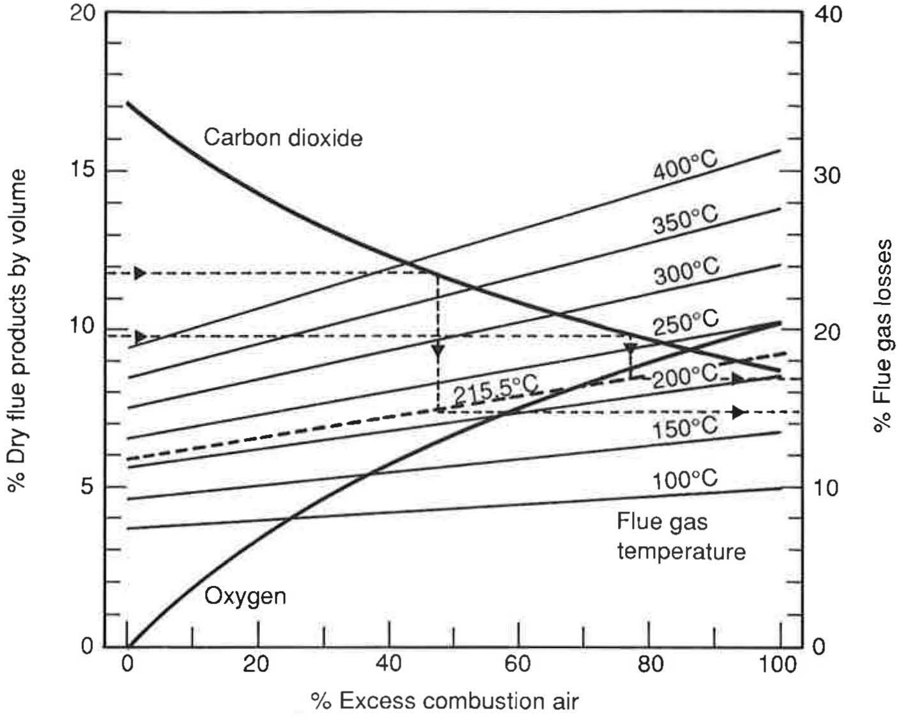


Fig 4 Flue gas losses - bitumous coal, illustrating example

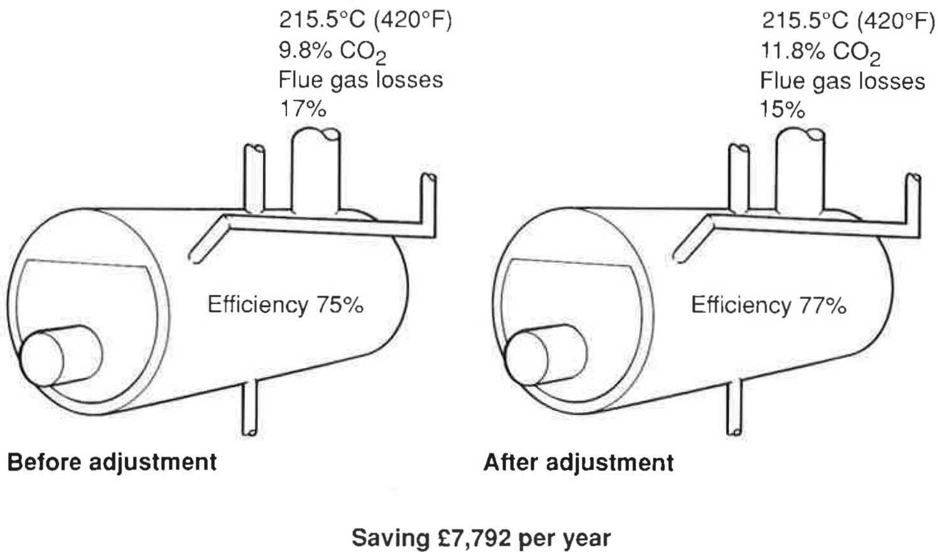


Fig 5 Flue gas losses - bitumous coal, illustrating example

On some old-type brick set boilers there may be difficulty in finding a suitable sample point which is unaffected by air ingress. Providing a sample point on these boilers may give rise to considerable re-pointing and sealing work. Whichever type of test equipment is used, it is most important that manufacturers' operating instructions are complied with and that the instruments are properly serviced.

Note that in practice the flue gas temperature may drop as the percentage of CO_2 rises.

- ***Cleanliness of heat transfer surfaces***

If the smoke tubes become fouled by soot and deposits, the amount of heat transferred from the hot flue gases to the water is reduced. This results in an increase in the temperature of the flue gases and therefore the flue gas losses, as shown in Fig 6. Boiler smoke tubes should be regularly cleaned to minimise the flue gas temperature rise. The boiler maker can advise how often the smoke tubes should be cleaned, or the maximum acceptable temperature rise before cleaning is required. A marked variation in draught at the boiler exit can also indicate the need for cleaning.

Soot blowers provide on-line cleaning and can reduce maintenance and retain the optimum efficiency period. Traditionally these comprised high-speed steam or compressed air jets, but recent developments have produced infrasonic and ultrasonic units

Example showing the effect of fouled heat transfer surfaces

A 56°C rise to 271°C (520°F) in the temperature of the flue gas containing 10.6% CO_2 will cause an increase of flue gas losses to 20%. For the Example Boiler, this would reduce efficiency by 3%, at an extra cost of:

$$£300{,}000 \times \frac{72 - 75}{72} = £12{,}500 \text{ per year}$$

- ***Economisers***

The flue temperature of modern three-pass wet back packaged shell boilers is normally too low to justify the installation of conventional economisers. Excessively low back end temperatures can lead to damage in boilers, flues and chimneys.

Older types of boiler, for example Lancashire boilers, are of relatively low efficiency. The flue

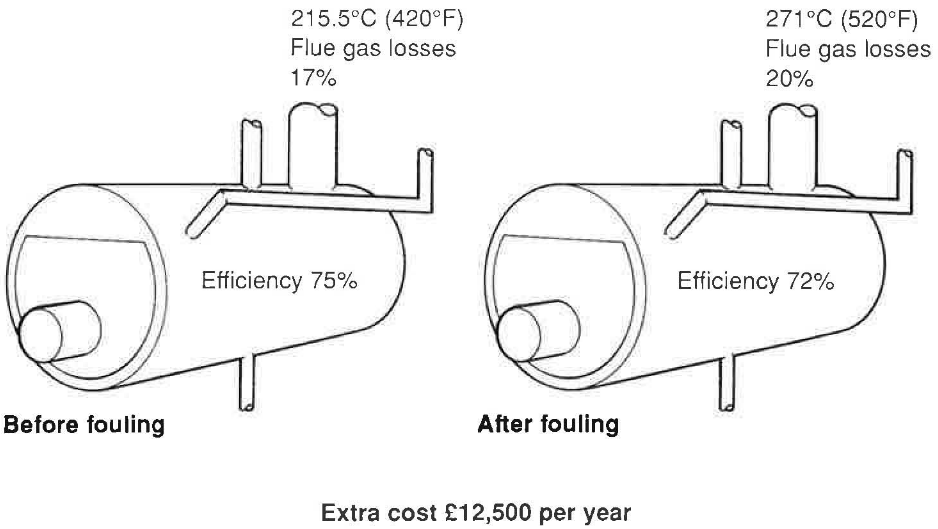


Fig 6 Decrease in efficiency due to flue gas temperature change

gases are at a sufficiently high temperature to justify passing the exit gases through an economiser to pre-heat the boiler feed water. Again care must be taken before fitting economisers to ensure that the metal surfaces are not cooled below the acid dewpoint, otherwise corrosion will take place. Manufacturers' recommendations must be sought on this point. An economiser fitted to a Lancashire boiler saves about 10% of fuel and can pay for itself in 12 months.

Retarders fitted in the smoke tubes of two-pass economic boilers can also save 10% of fuel.

- ***Flue dampers***

It may be economic in some cases to fit isolating dampers to individual boiler flues. In order to estimate savings, consideration should be given to the combination of boiler schedules and flue conditions, and suppliers should be consulted.

3.5 Radiation loss

Radiation loss refers to heat loss from the surface of the boiler. It is better defined as radiation and convection losses, but the term radiation only is normally used in this context.

Radiation loss on modern boilers can be around 1% or less of the heat input at maximum rating. It may, however, be considerably higher on older boilers and it can be as high as 10% where insulation is in poor condition and the boiler design is old. Radiation is not readily measurable on a boiler; however, experience has shown that in the case of conventional designs, these losses fall within ranges for the various types of boiler. These ranges are given in BS 845: 1987. Other principal heat losses included with radiation in this booklet are those due to unburnt gases (mainly carbon monoxide) in the flue gas, unburnt carbon and sensible heat in ash.

Radiation loss is constant whilst the boiler is firing, and if it is running under low-load conditions this loss represents a higher proportion of the total fuel used than under high fire conditions.

Example of the effect of part-load running

If the load in the Example Boiler is supplied by two boilers running part-loaded at half of their maximum rating, and the true radiation loss is 2% at full load, then the total radiation loss will be doubled to 4%; this will add an extra £6,000 (2% of £300,000) to the annual fuel bill, compared with the situation where the load is supplied by one boiler at full load.

3.6 Firing schedules

The quantity and profile of the steam required by a plant throughout the day and week should be reviewed frequently, and the minimum number of boilers used. It may be worth temporary loss or reduction of steam supply in the event of a boiler failure in order to run at optimum efficiency. An assessment should be made of the time required either to bring a standby boiler on-line or to rectify likely faults.

Steam valves isolating one boiler from another sometimes pass steam when closed, and they should be regularly maintained to prevent leakage into standing boilers. If boilers are required to stand for long periods blanks should be inserted into the flanges next to the valves.

3.7 Blowdown

It is necessary to blowdown steam boilers regularly in order to:

- remove sludge composed of precipitated salts;
- prevent scaling up of tubes and tube plates on the water side;
- avoid priming (foaming) and carry-over into steam mains.

To avoid unnecessary loss of heat, the level of blowdown should be kept as low as possible, compatible with maintaining the recommended level of total dissolved solids. The use of heat loss from blowdown for some useful purpose should be considered, e.g. to pre-heat feed water. The rate of heat loss due to blowdown is shown in Fig 7.

> ***Example***
>
> In the case of the Example Boiler, blowdown accounts for 3% of the losses in the boiler. This represents blowdown of approximately 12.5% of the evaporation rate; which is also approximately 12.5% of the feed water, and costs £9,000 per year in lost fuel, plus the cost of the feed water and the water treatment where applicable.

The above example is indicated on Fig 7, to show how the graph is used. A high blowdown loss may well justify expenditure on heat recovery equipment or water treatment plant. If all the factory condensate is returned to the hot well, blowdown can be drastically reduced.

Where more than one boiler is operated on an intermittent system, it is advantageous to stagger or automatically time the blowdown cycle in order to spread the availability of waste heat more evenly. This will enable waste heat recovery to be more economic, because the equipment required will be smaller and will run for a higher proportion of the time, thereby proving more cost-effective.

One of the most simple ways to recover heat from blowdown is through direct use of the flash steam, which forms due to evaporation as the pressure falls through the blowdown valve. This is pure water, with no dissolved solids, and can therefore be added directly to the make-up water for the boiler. Additional heat can be recovered from the remaining blowdown by installing a heat exchanger to pre-heat boiler feed water. (Fuel Efficiency Booklet No 2 - 'Steam' - covers this subject in greater detail.)

3.8 Water treatment

Chemical water treatment is necessary to:

- prevent scale formation in boilers and ancillary equipment which leads to higher flue gas temperatures and lower boiler efficiency (Fuel Efficiency Booklet No 2 - 'Steam' - gives examples of heat transfer being affected by the formation of scale.);

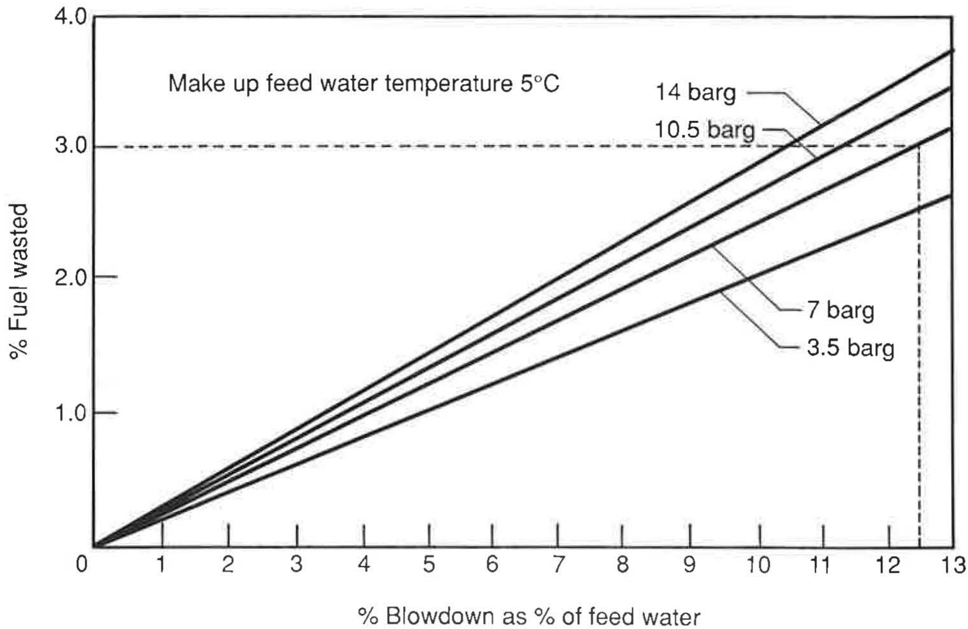


Fig 7 Percentage of fuel wasted in blowdown

- control sludge and scale formation in the boiler and to reduce blowdown;
- reduce or eliminate the corrosion of the boiler and steam mains (from carbon dioxide in the steam) which leads to higher maintenance costs;
- avoid contamination of the steam by boiler water, which can be carried over by priming;
- minimise corrosion due to dissolved oxygen in the feed water. Adequate treatment should be given, following the advice of a competent water treatment specialist.

Over-dosing can be avoided by ensuring that operatives are not heavy-handed and by switching off treatment pumps when boilers are not operating. Ideally boiler-dosing equipment should be controlled by the operation of the feed water pump. The water treatment facilities should be appropriate to the requirements. To ensure this, more than one opinion and quotation should be obtained from water treatment firms, the boiler manufacturer and from the insurance company. The cheapest is not necessarily the best buy. The boiler should not be used as a chemical precipitation vessel - it has been designed to produce dry steam.

If the quality of the water treatment is improved and/or the proportion of returned condensate is increased, this should reduce the amount of blowdown necessary.

Total dissolved solids levels are easily checked by measuring water density (by special hydrometer) and temperature. Boiler water test kits are cheap and relatively easy to use, and can be purchased through a water treatment specialist. Detailed recommendations on treatment can be found in BS 2486: 1978 - 'Recommendations for treatment of water for land boilers'.

3.9 Condensate recovery

If the feed water temperature is low, the cause should be discovered. It could be due to:

- a low rate of condensate return;
- the lack of insulation on the condensate return pipes (although this may not be important in systems exclusively used for space heating);
- losses from the feed tank either as heat through the wall or as overflow.

As much condensate as is economically possible should be returned from sources where there is no likelihood of contamination. This will save heat, make-up water and any chemicals used in water treatment, as well as reducing blowdown losses. The possible fuel savings resulting from increased condensate return are shown in Fig 8.

Where there is a danger of feed water contamination, automatic dumping by measuring the conductivity of the condensate is common. The monitors should be sited so that only the contaminated condensate is dumped and not the whole of the condensate steam. In large, multiple installations it may be necessary to monitor and dump each condensate source independently. Without special arrangements it is rarely possible to use feed water in excess of 82°C (180°F) due to cavitation problems on the feed pump, although the feed water temperature can be raised above this level after the pump if an economiser is fitted. When in doubt, the boiler or feed pump manufacturer should always be consulted.

Fuel Efficiency Booklet No 2 - 'Steam' - has a section on heat recovery techniques which covers this subject in more detail.

Example of possible savings from increased condensate return

If the feed water temperature can be raised from 17°C (62.5°F) to 38°C (100°F) by increasing the amount of condensate returned at 38°C (100°F) from 25 to 100%, a saving of 3.3% boiler fuel will result. For the Example Boiler the savings would amount to £9,900 per year (see Fig 9). Further savings will also accrue due to an accompanying reduction in blowdown losses.

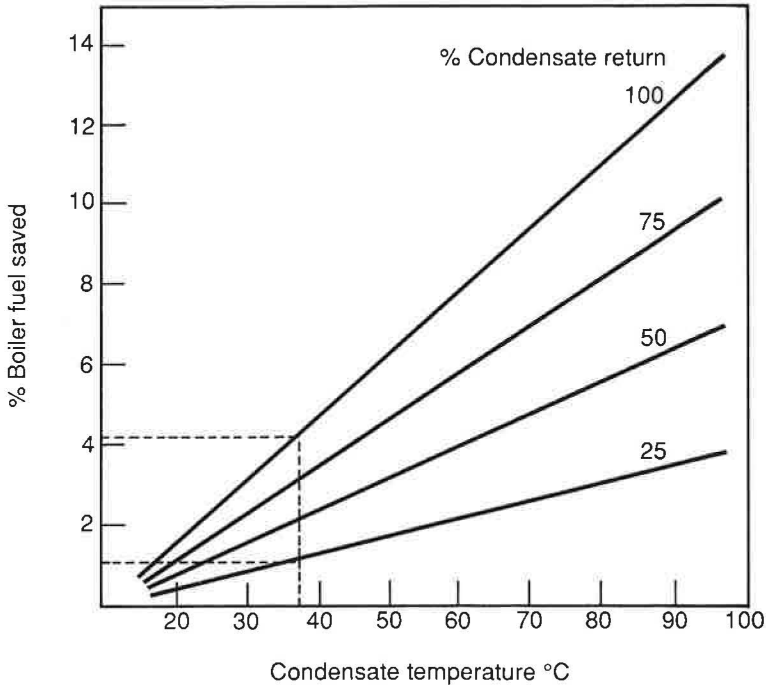
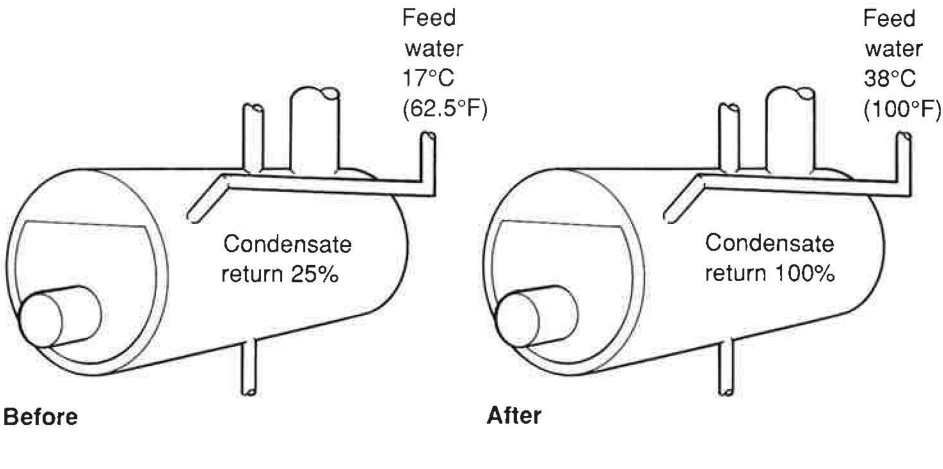


Fig 8 Fuel saved by condensate return



Saving £9,900 per year

Fig 9 Change in operating cost due to extra condensate return

3.10 Steam and hot water services

- ***Steam supply***

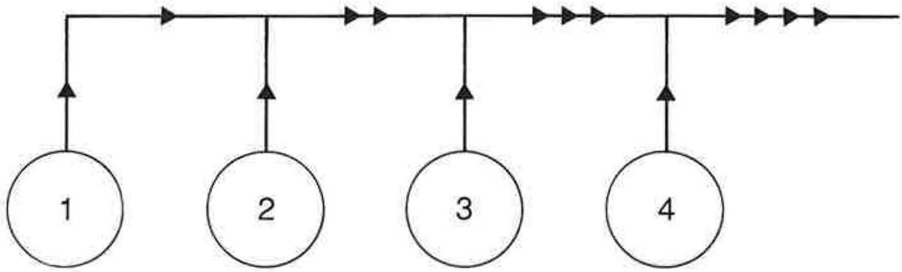
Steam boilers should not be operated below the minimum pressure recommended by the maker. If the steam using equipment requires a significantly lower pressure, consideration should be given to de-rating the boiler or replacing it. Alternatively the high pressure steam could be used in a steam turbine to generate electricity. This will minimise distribution heat losses.

The pressure drop in the main steam lines up to the point of use will need to be checked, so that the initial optimum pressure can be determined.

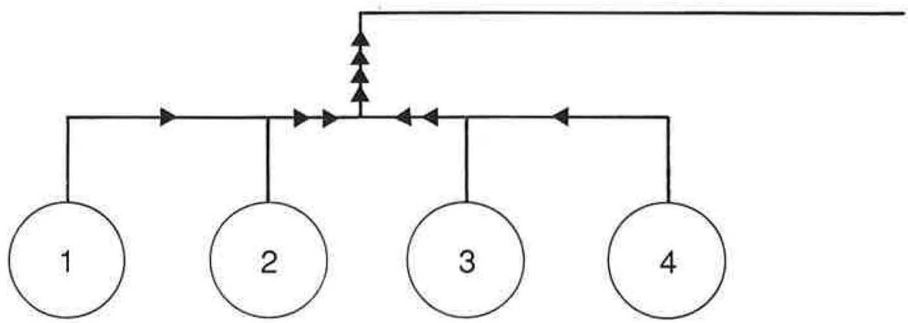
- ***Header connections on boiler plant***

Where more than two boilers are connected into a common header it is important that the layout is correct. Fig 10 shows correct and incorrect methods of connecting four boilers into a header.

Incorrect connection can lead to the following sequence of events occurring. One or more boilers could receive an excess steam demand of up to 25%, e.g. boilers 3 and 4 in Fig 10a. Due to limited heat input, the boiler(s) will respond to this demand with a drop in pressure, accompanied by an expansion of the steam and water mixture in the boiler, resulting in foaming and carryover. In severe cases this can cause loss of water from boilers, leading to boiler lock-out due to low water, with the load then being thrust



(a) Incorrect method of connecting steam boilers to a distribution system, causing excessive demand on boilers 3 and 4



(b) Correct method of connecting steam boilers to a distribution system, demand on all boilers virtually balanced

Fig 10 Methods of connecting steam boilers to a distribution system

upon the remaining boilers. These in turn will become overloaded and the system cascade, locking out all the boilers at a time when their outputs are all needed. This effect is caused by the pressure loss along the header, which increases proportionally with the square of the steam flow.

In Fig 10a, the pressure in the header will fall severely from the point of connection at boiler 1 to those at boilers 3 and 4, as the successive outputs of the boilers are added into the header; boilers 3 and 4 could become severely overloaded. The pressure difference, and hence boiler loading, between boilers 1 and 2 would be much less, about 5%, which the firing equipment could handle. To avoid problems, not more than two boilers should discharge into a header or sub-header, as shown in Fig 10b.

Many installations have boilers incorrectly connected to the distribution system, resulting in the problems described. It is worthwhile changing the connections to overcome these problems. As a temporary measure, the outlets from all boilers can be fitted with limiting orifice plates designed to lose about 3 bar pressure at full boiler rating.

Loading problems can exist with all boilers, irrespective of fuel used, and if allowed to persist can seriously affect the reliability and efficiency of the whole steam generating and using plant.

- ***Pipework***

All piping and valves conveying steam and condensate should be properly lagged and weatherproofed, except where they are exclusively part of a controlled heating system, and the steam supply should be turned off when there is no heating requirement. Insulating large diameter pipes pays off in a few weeks. Insulating small diameter pipes pays off in a few months. Often in older installations steam valves and flanges were not lagged, but it is now economic to do so.

Procedures should be established such that insulation is examined regularly and promptly replaced where necessary, particularly on equipment or pipes which have to be dismantled or repaired. The economic thickness of the insulation should be reassessed when replacing lagging; some insulation contractors and equipment suppliers may still be working on uneconomic thicknesses. Further information can be found in Fuel Efficiency Booklet No 8 - 'The economic thickness of insulation for hot pipes'.

Where cavitation may result from increased water temperature due to lagging the feed water pipes, there should be an adequate head on the suction side of the boiler feed pump.

Example of the effects of insulation

In the Example Boiler, 30 m (100 ft) of unlagged 80 mm (3 in) pipe carrying steam at 7 barg (100 psig) and 170°C (338°F) will lose heat at the rate of some £1,875 per year.

An uninsulated valve is equivalent to 1 m (3 linear feet) of uninsulated pipe; at 7 barg (100 psig) an 80 mm (3 in) valve will lose heat equivalent to £56 per year. An uninsulated flange will lose half this.

4. Checklist of money-saving procedures

1 Measure the output of steam from boilers either directly by means of a steam meter, or indirectly by metering the total boiler feed water and estimating the blowdown. The ratio of steam to fuel is the main measure of boiler efficiency, and it should be maintained at a level compatible with good practice.

2 Continuously log boiler performance so that signs of deterioration soon become evident, enabling corrective maintenance to be carried out. Examples of daily log sheets and weekly summary sheets for steam and hot water boilers are given in Figs 11, 12, 13 and 14.

3 Meter feed water.

4 Check steam meters occasionally, as their performance deteriorates with time due to erosion of the metering orifice or pitot head. Steam meters only give correct readings at the calibrated steam pressure - re-calibration is required if the steam pressure is changed, and the meter readings should be corrected for changes in steam volume. See Energy Efficiency Office (EEO) Good Practice Guide No 18 -'Reducing consumption by steam metering' - for more detailed information.

5 Isolate pipelines not in use and disconnect redundant pipes. Regular surveys should be made, particularly if the pipework uses are frequently changed.

6 Ensure that accounting for input and output of energy in boiler houses is as realistic as possible. Fuel stock-taking should be accurate.

7 Improve housekeeping procedures, as these are likely to result in better working conditions and morale in the boiler house.

8 Review the repair and maintenance procedures in the boiler house, especially where they affect the firing equipment, controls and instrumentation. There should be a regular routine for cleaning boiler heat transfer surfaces or smoke tubes. Any useful instrumentation or equipment which has fallen out of use, for example water meters, temperature indicators or recorders and economisers (where applicable), should be repaired and brought back into use.

9 Periodically check the state of furnace brickwork and flues. In older boiler installations, underground flues may need to be checked for water inleakage.

10 Repair steam leaks without delay. Such leaks not only waste energy but are also potential safety hazards.

11 Give special consideration to the boiler operators. Ensure that they are familiar with correct operational procedures. Courses are available for boiler operators and could prove a worthwhile investment.

12 Investigate the possibility of implementing heat recovery systems. See EEO Good Practice Guide 30 - 'Energy efficient operation of industrial boiler plant' - for more detailed information on available techniques.

Daily Log Sheet - Steam Boilers

Date: | Plant:

Time	Boiler No	Steam		Water				Flue gases			Draught		Fuel					Air	Comments
		Pressure (bar)	Temp. (°C)	Temp. econ. inlet (°C)	Temp. boiler inlet (°C)	Meter reading feed water (litres)	Meter reading make-up water (litres)	Temp. boiler outlet (°C)	Temp. econ. outlet (°C)	CO_2 or O_2 (%)	Pressure in combustion chamber (bar)	Pressure at boiler outlet (bar)	Flow meter (kg.m^3 or litres)	Return meter (kg.m^3 or litres)	Flow temp. (°C)	Return temp (°C)	Ashes (kg)	Outside temp. (°C)	
Total																			
No of readings																			
Average																			

Daily Summary

Fuel type and grade ....

Density (20/20) ....
or Calorific Value........................ kJ/kg or kJ/m^3

Fuel used (metered)..

Fuel used (corrected to 20°C)..........................

Fuel used.. kg

Evaporation of steam: total.......................... kg

Evaporation of steam per kg of fuel...............kg

Ashes: total.. kg = ...% of fuel

Feed water: Meter reading (start of day)...kg
Meter reading (end of day)...kg
Difference ....kg

Make-up water ....kg = ...% of evaporation

Blowdown (total) time ....   Quantity..

Operators on duty:	Shift 1	Shift 2	Shift 3	**Comments:**

Fig 11 Example daily log sheet for steam boilers

Daily Log Sheet - Hot Water Boilers

Date:	Plant:

Time	Boiler No	Water					Flue gases			Draught		Fuel					Air	Comments
		Working pressure (bar)	Temp. boiler outlet (°C)	Temp. econ. inlet (°C)	Temp. boiler inlet (°C)	Meter reading (kJ or litres)	Temp. boiler outlet (°C)	Temp. econ. outlet (°C)	CO_2 or O_2 (%)	Pressure in combustion chamber (bar)	Pressure at boiler outlet (bar)	Flow meter (kg.m^3 or litres)	Return meter (kg.m^3 or litres)	Flow temp. (°C)	Return temp (°C)	Ashes (kg)	Outside temp. (°C)	
Total																		
No of readings																		
Average																		

Daily Summary

Fuel type and grade..

Fuel used (metered)..

Fuel used..kg

Evaporation of steam: total..............................kg

Ashes: total..kg = ...% of fuel

Density (20/20) ....

or Calorific Value .... kJ/kg or kJ/m^3

Fuel used (corrected to 20°C) ....

Total water circulated.. litres

Average temperature difference .... °C

Total heat output.. kJ

Total heat per kg of fuel.. kJ

Make-up water ....litres = ...% of total

Operators on duty:	Shift 1	Shift 2	Shift 3	**Comments:**

Fig 12 Example daily log sheet for hot water boilers

Weekly Summary Sheet - Steam Boilers

Week commencing				**Plant**			
Date	**Fuel consumed (kg)**	**Ashes (kg or %)**	**Water evaporated (kg)**	**Evaporation per kg or m^3 of fuel (kg)**	**Make-up water (% of total)**	**Hours operating**	**Comments**
Total							
No. of readings							
Average							

Total amount of fuel used .... kg at £ ....per kg
litres (corrected to 20°C) at £ ....per litre (or cubic metre = 10^3 litres)
Weekly total fuel costs £ ....
Costs of fuel for evaporating 1000 kg of water £ ....
Comments on weekly summary...
....
....

Fig 13 Example weekly summary sheet for steam boilers

Weekly Summary Sheet - Steam Boilers

Week commencing				Plant					
Date	**Fuel consumed (kg)**	**Ashes (kg or %)**	**Total water circulated (kg)**	**Average temperature difference (°C)**	**Total heat output (kJ)**	**Heat output per kg or m^3 of fuel kJ**	**Make-up water (% of total)**	**Hours operating**	**Comments**
Total									
No. of readings									
Average									

Total amount of fuel used.................................. kg at £ .... per kg

.... litres (corrected to 20°C) at £.................... per litre (or cubic metre = 10^3 litres)

Weekly total fuel costs £ ....

Costs of fuel per MJ £......................................

Comments on weekly summary ....

....

....

Fig 14 Example weekly summary sheet for hot water boilers

5. Sources of further information

- ***British Standards:***

BS 845: 1987 - Methods for assessing thermal performance of boilers for steam, hot water and high temperature heat transfer fluids

BS 2486: 1978 - Recommendations for treatment of water for land boilers

Copies of these British Standards are available from:

British Standards Institution
Sales Department
Linford Wood
Milton Keynes
MK14 6LE

- ***British Coal***

Guidance on all aspects of industrial coal technology, including stocking and the handling of coal and ash is available from:

British Coal Technical Services
Hobart House
Grosvenor Place
London
SW1X 7AE
Tel No: 071-235-2020

- ***EEO Publications:***

Good Practice Guide 18 - Reducing energy consumption costs by steam metering

Good Practice Guide 30 - Energy efficient operation of industrial boiler plant

Good Practice Case Study 153 - Differential drainage and boiler return system

Copies of these publications and other literature applicable to the economic use of coal-fired boiler plant are available from:

Energy Efficiency Enquiries Bureau
ETSU (Energy Technology Support Unit)
Harwell
Oxon
OX11 0RA
Tel No: 0235 436747 Fax No: 0235 432923

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